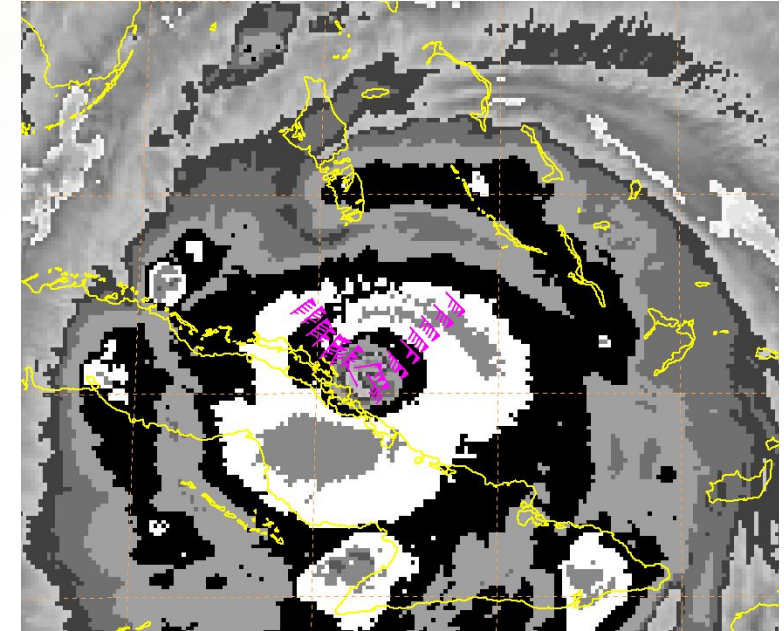
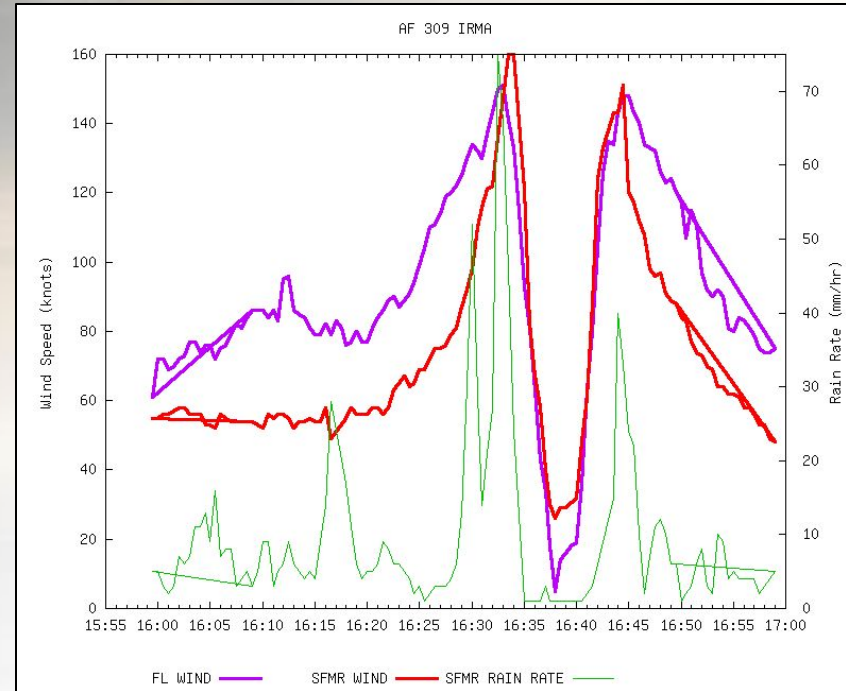


NHC's Use of Aircraft Data in Hurricane Analysis



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Overview of Aircraft Observations

- Flight-level observations, SFMR, dropwindsondes, and radar
- Used subjectively by the Hurricane Specialists to assist in analysis and short-term forecasting of location, intensity, size, and structure
- Provide input to forecast models
 - Directly (e.g., direct assimilation of dropsondes, flight level data, and radar into models)
 - Indirectly to both dynamical and statistical models, through forecaster specification of the storm “compute” parameters (e.g., MSLP, RMW, V_{\max} , 34/50/64-kt radii)
- Best Track analysis

What is Tropical Cyclone Intensity?

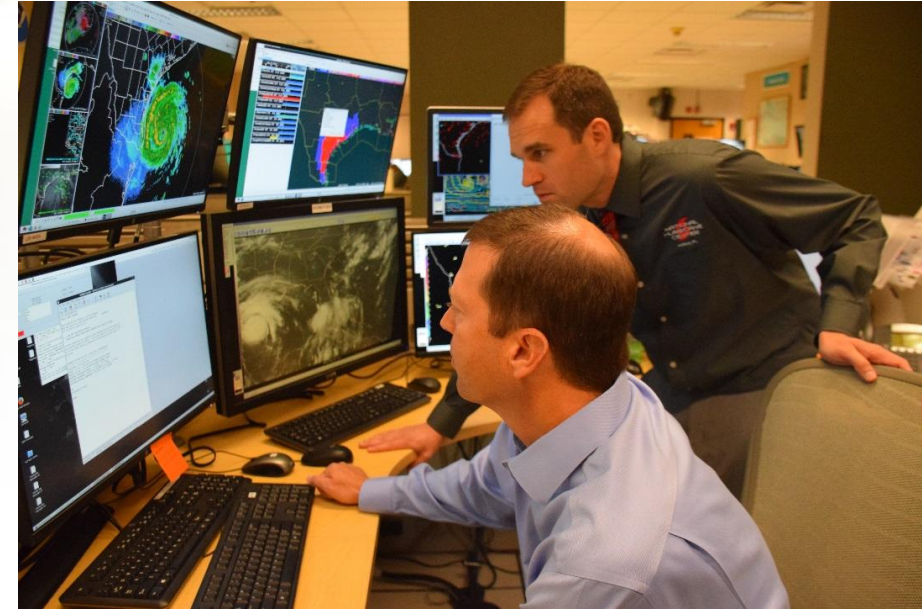
- ***Maximum sustained surface wind (MSSW)***
 - Highest 1-min average wind at 10 m with unobstructed exposure associated with that weather system at a particular point in time
 - *Not* the highest 1-min wind anywhere within the circulation
 - Observations can be discounted if they are primarily associated with something other than the TC circulation
- Intensity is *not* the highest 1-min wind occurring over an interval of time
 - Advisory intensity should correspond to the *expected* value of the MSSW at advisory time



Eye of Hurricane Florence – courtesy NASA

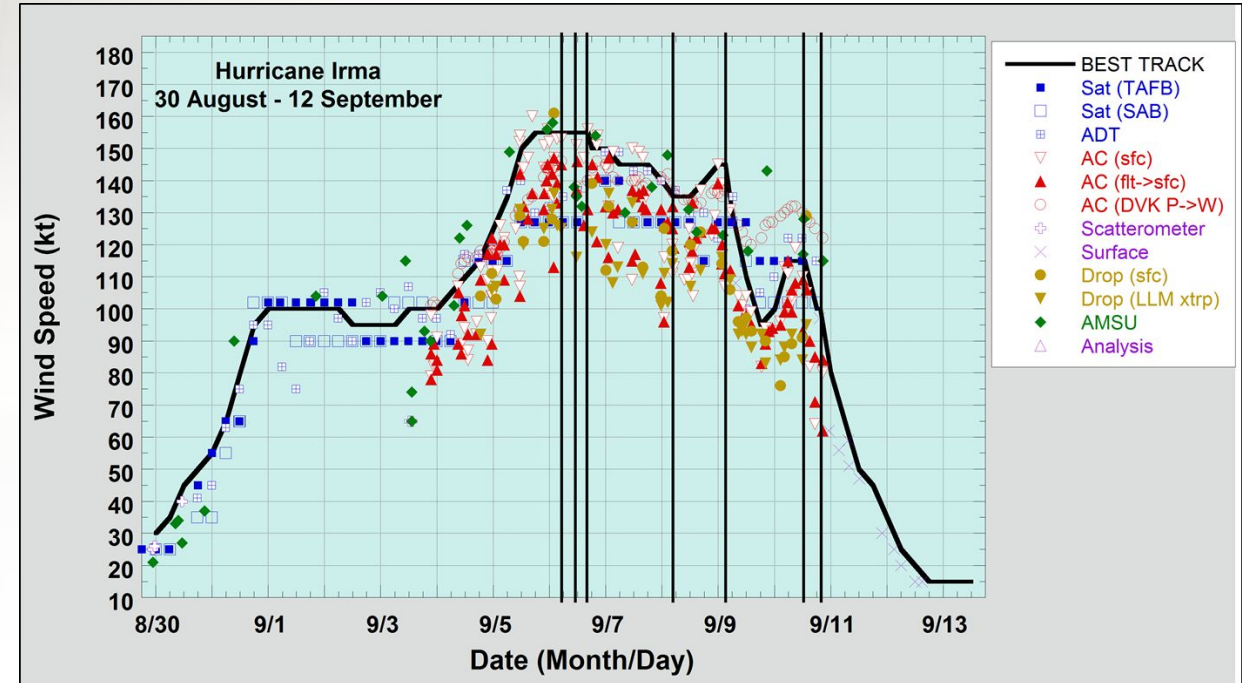
Representative Intensity

- In the best track, intensity is representative of that 6-h period and doesn't generally try to capture fluctuations that occur on time scales < 24 h
 - Exceptions are made for assessing peak intensity or intensity at a specific point/location, such as landfall
- NHC forecasters balance under-sampling against representativeness and evaluate whether an observation reflects the TC's intensity, some transient feature, or is simply unreliable
 - If a piece of data doesn't fit, it's our job to be skeptical and assess the data in context with other available data to make the best analysis

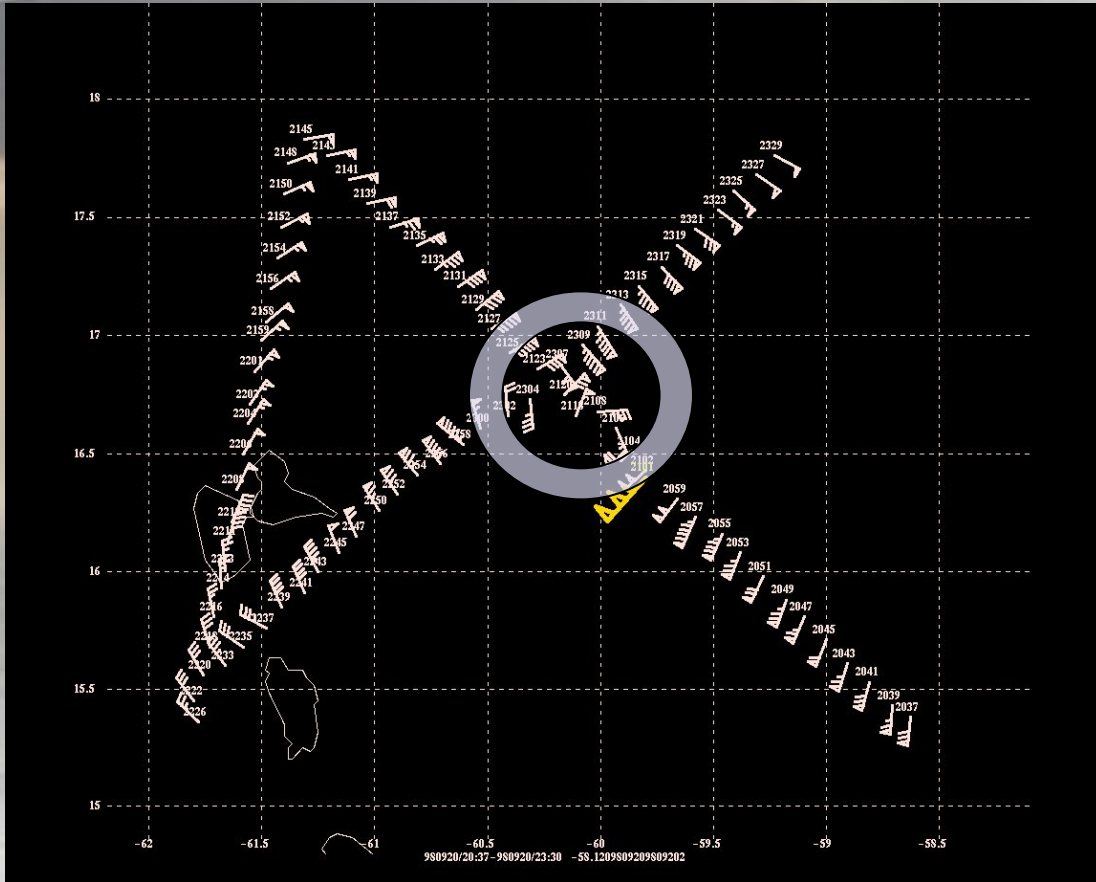


Intensity and Observations

- With very, very few exceptions, direct observations of the maximum sustained surface wind in a tropical cyclone are *not available*
- Aircraft flight-level winds
 - Require vertical adjustment to the surface
 - Sampling limitations
 - Representativeness issues
- SFMR winds
 - Sampling limitations
 - Representativeness issues
 - Rain/wind separation
 - Calibration
- Dropsondes
 - Temporal interpretation/representativeness
 - Point observations with severe sampling considerations

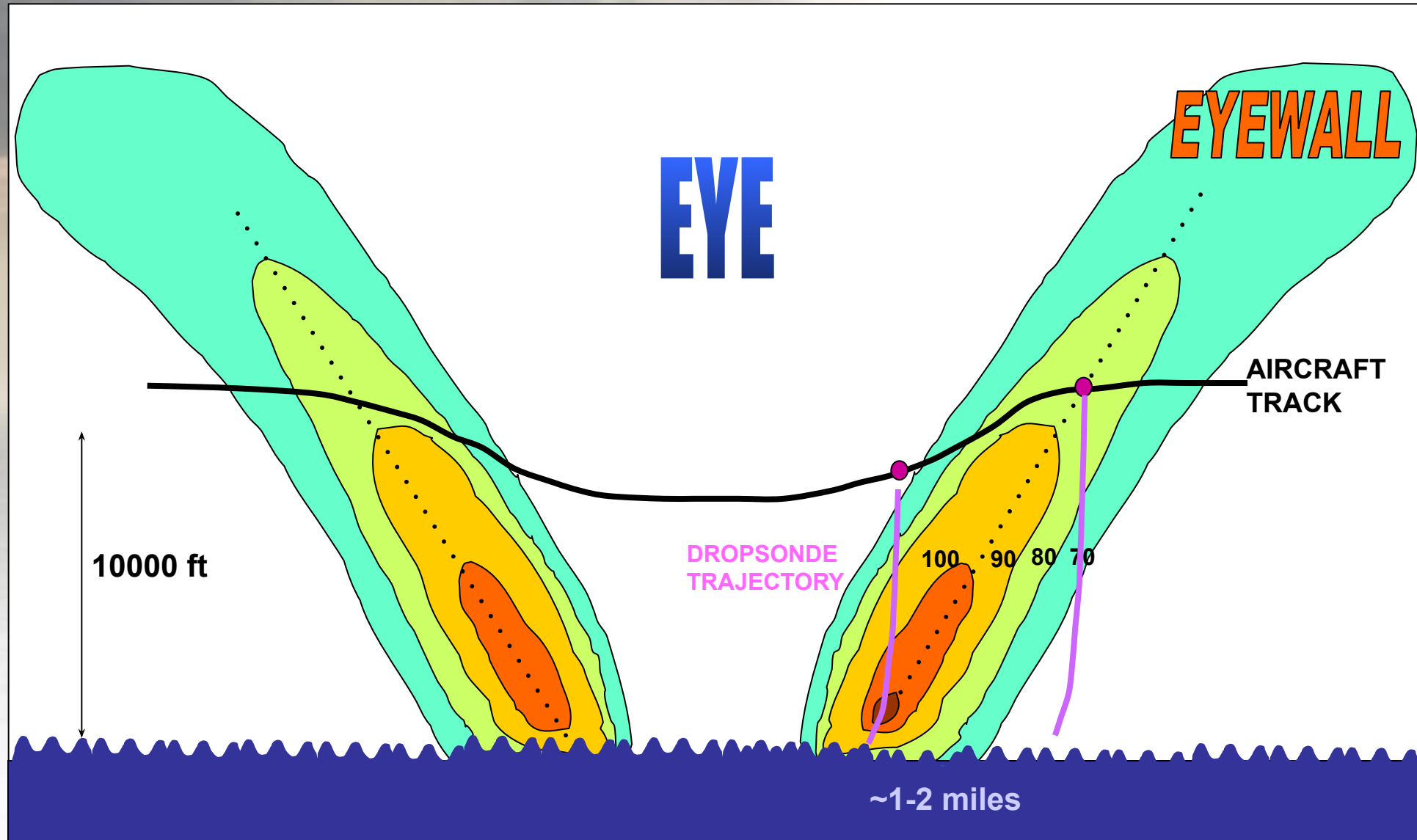


Intensity and Observations



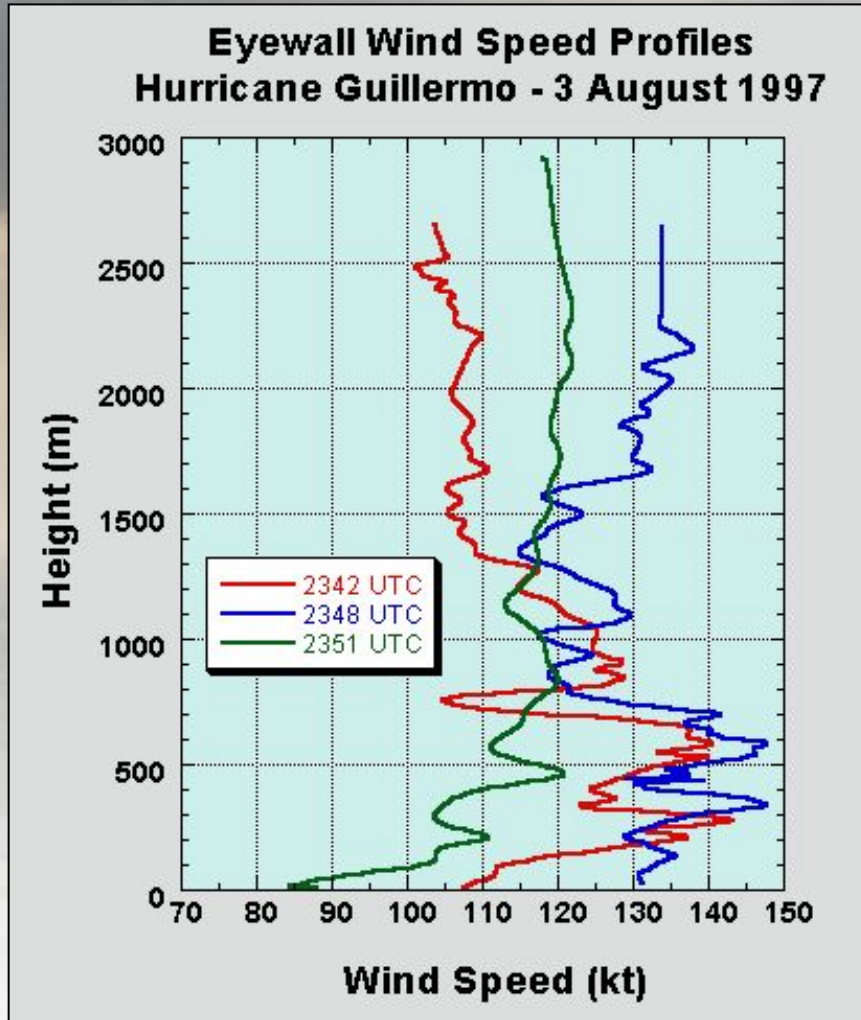
- Peak winds in the hurricane eyewall may occur in a band only a few km across, and be located anywhere in an eyewall that is sampled at only four locations over a period of 1.5 hr
- Odds that the peak sustained winds are observed by aircraft or encountered by coastal surface stations are exceedingly small

Representativeness of Dropsondes

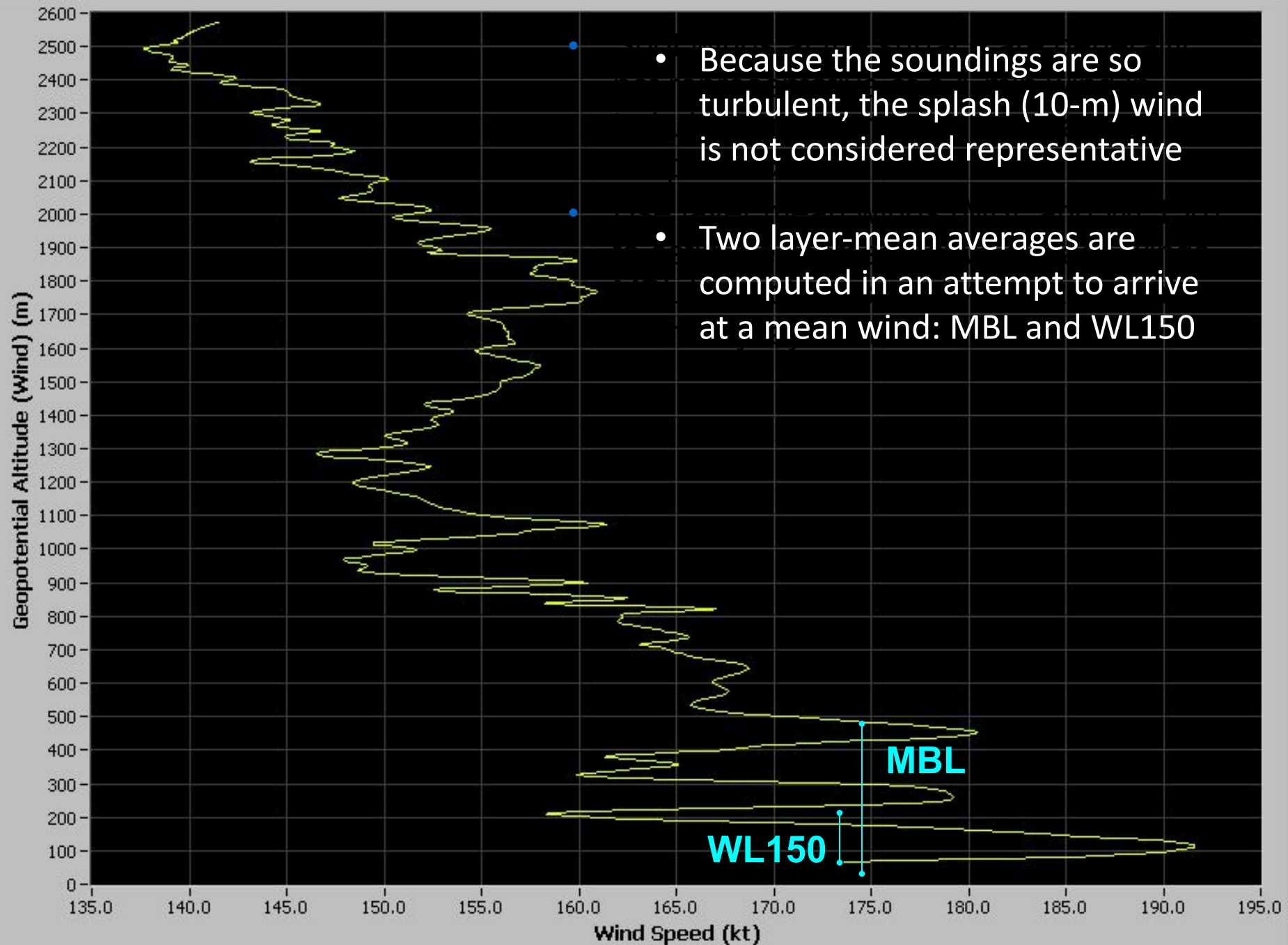


Dropsonde Representativeness Issues

Large Variability in Space and Time

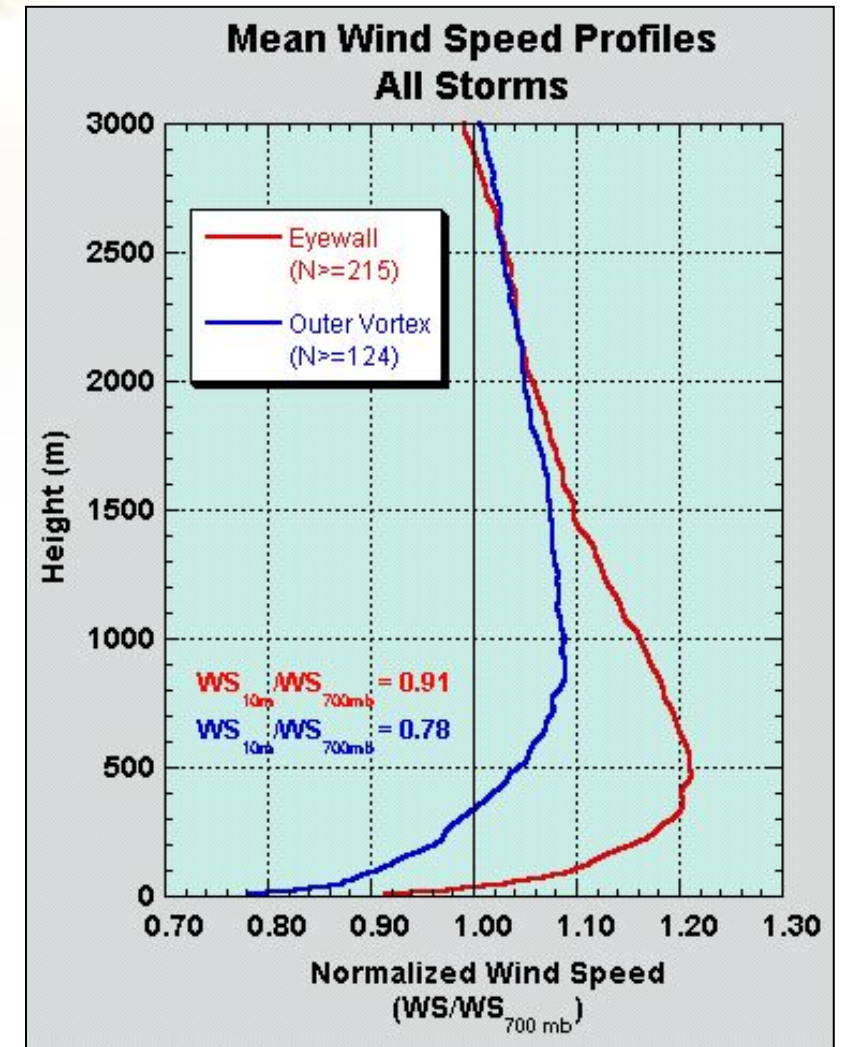


- Three dropsondes released in different portions of the hurricane eyewall recorded surface winds differing by ~45 kt!



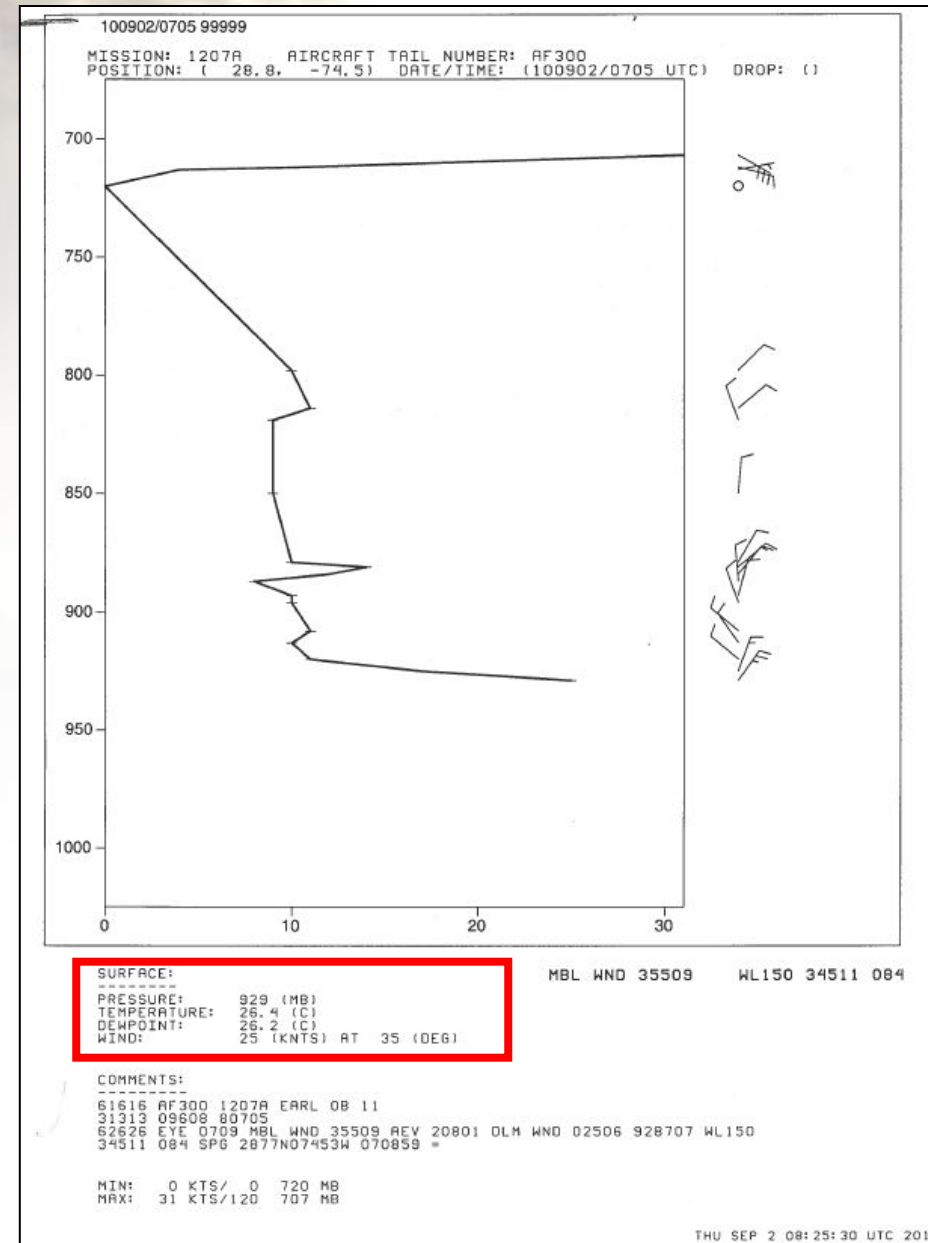
Dropsonde Winds

- Once the low-level means are computed, they are adjusted to the surface using a mean profile determined from many soundings
 - MBL wind of 150 kt * 0.8 = estimated surface wind of 120 kt
 - WL150 wind of 165 kt * 0.83 = estimated surface wind of 137 kt

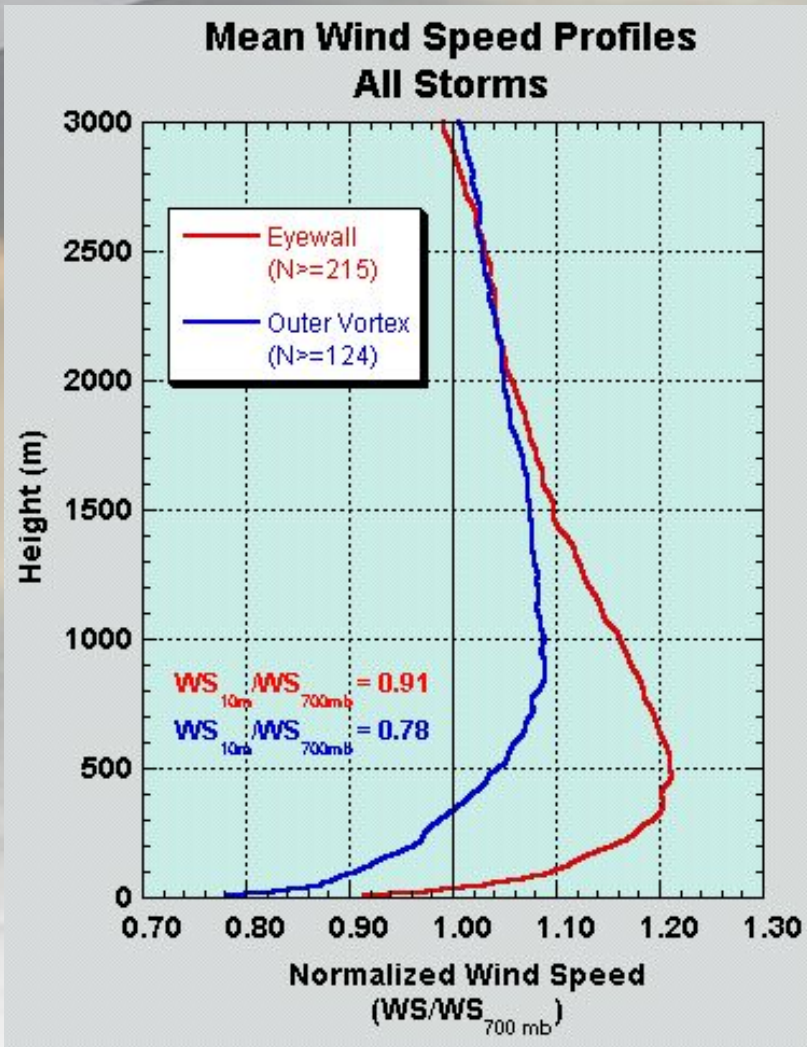


Central Pressure from Dropsonde

- Center (eye) drops are released at the flight-level wind minimum, but may drift away from surface minimum
- Rule of thumb for estimating MSLP is to subtract 1 mb from the sonde splash pressure for each 10 kt of surface wind reported by the sonde
 - Splash pressure: 929 mb
 - Surface wind: 25 kt
 - Estimated MSLP: 927 mb



Flight-Level Adjustments to Surface



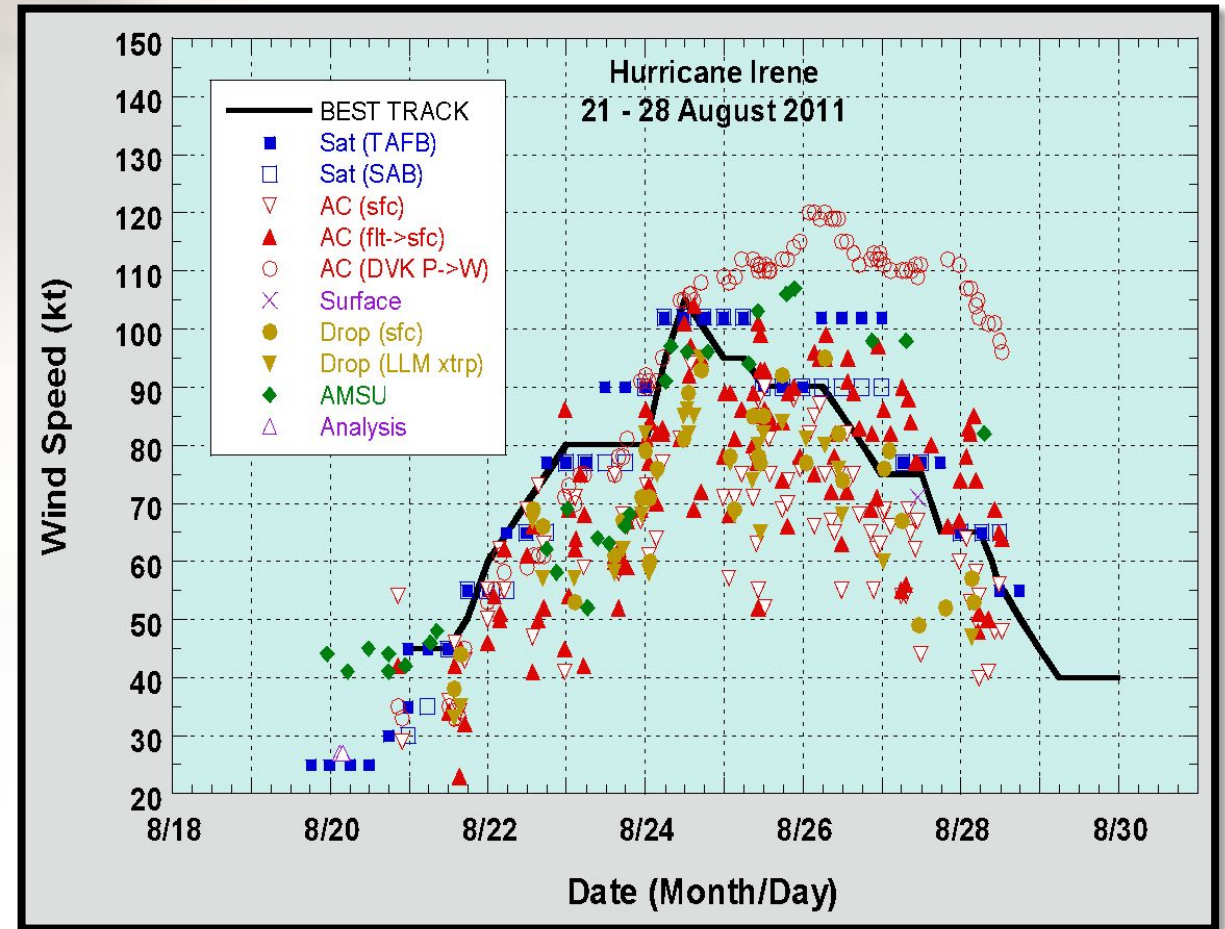
- Franklin et al., 2003: GPS dropwindsonde wind profiles in hurricanes and their operational implications., *Wea. Forecasting*, **18**, 32-44
- Large sample of GPS drops used to define mean eyewall and outer vortex wind profiles
- Profiles used to develop adjustment factors for common reconnaissance flight levels
- On the right side of the eyewall near the flight-level RMW, mean surface-700 mb ratio was near 86%
- Because the true flight-level maximum is likely not sampled, max surface wind is often estimated to be 90% of observed maximum flight-level wind

Estimating Intensity From Flight-Level Wind

Reference Level	Adjustment Factor
700 mb	90%
850 mb	80%
925 mb	75%
1000 ft	80%

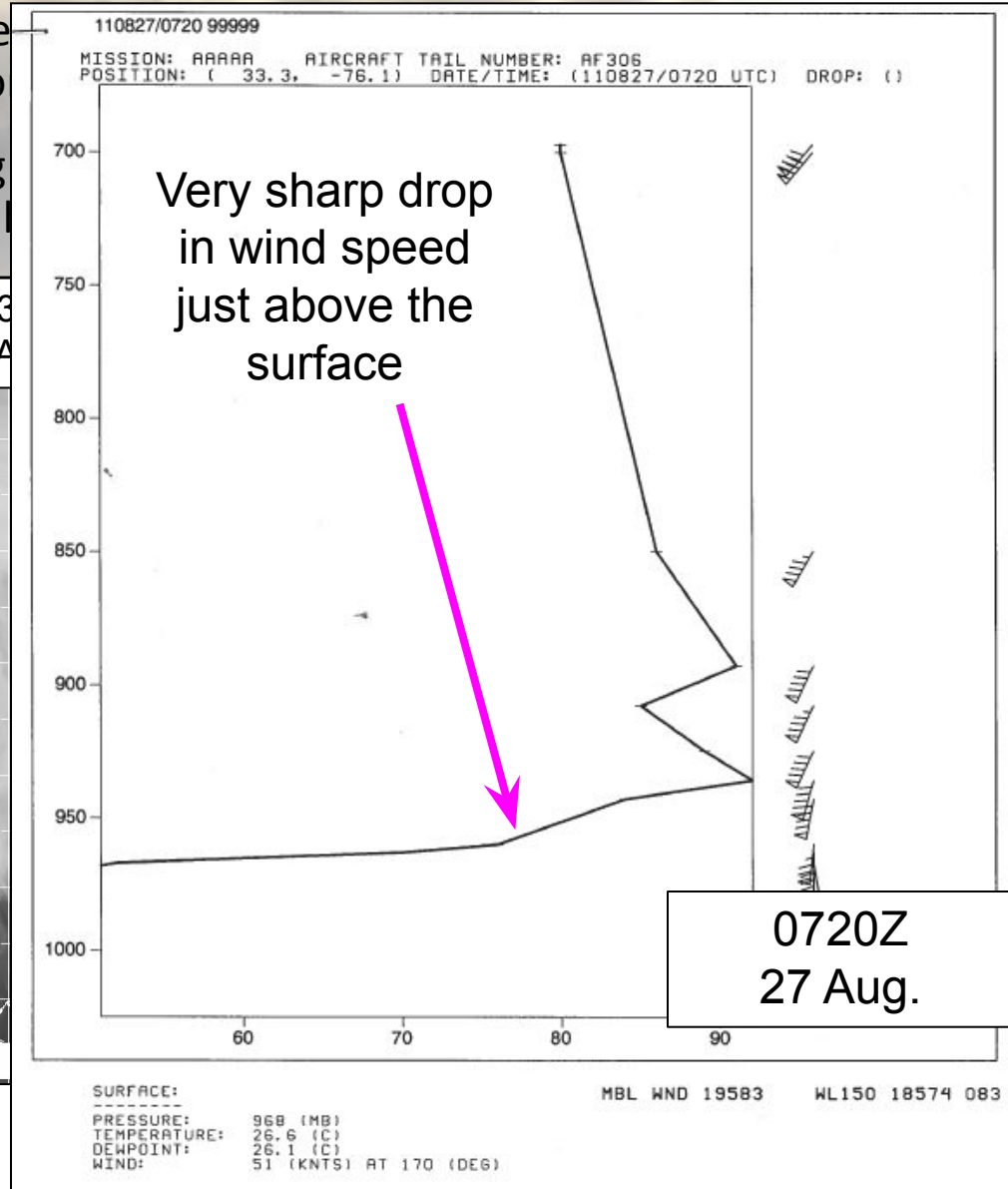
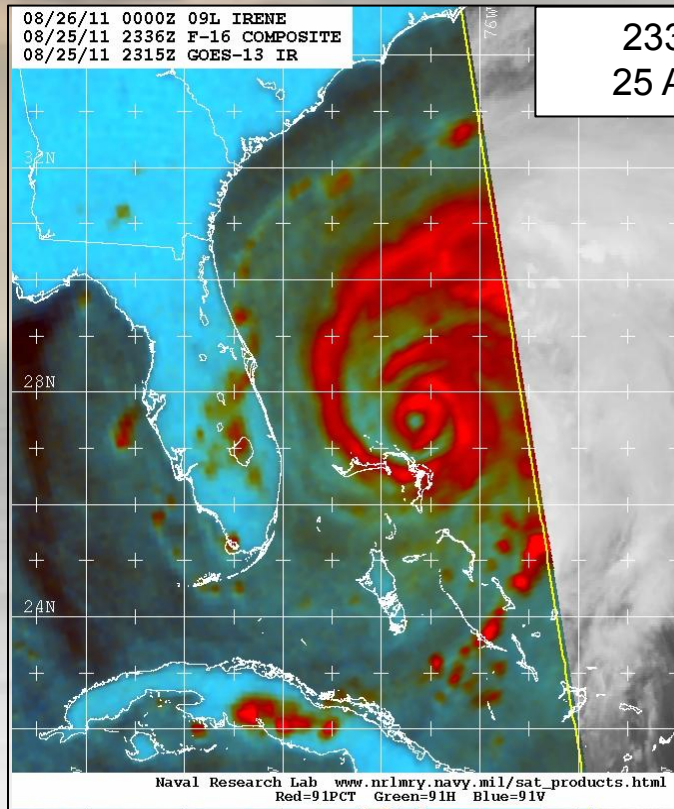
Variability of Standard Adjustment

- Surface to 700-mb wind ratios vary from storm to storm, and can range from ~70% to > 100%
- However, departures from standard adjustment can't be determined from just a few dropsondes
 - Convective vigor
 - Eyewall structure, cycle, RMW
 - Low-level stability/cooler waters



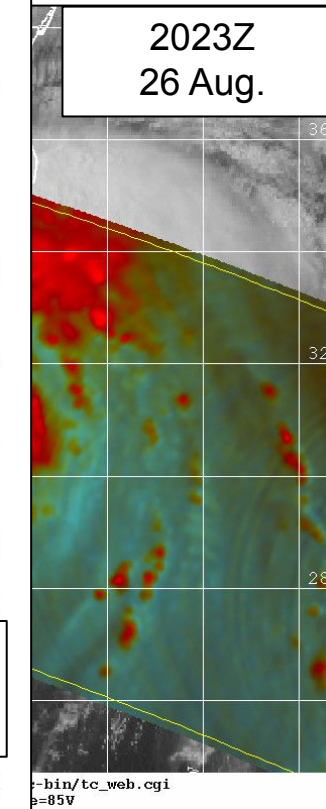
Departure from Standard Adjustments

- A failed eyewall replacement cycle that were unable to transport storm energy
- By this point, NHC was forecasting initial intensity that was 10 kt too low



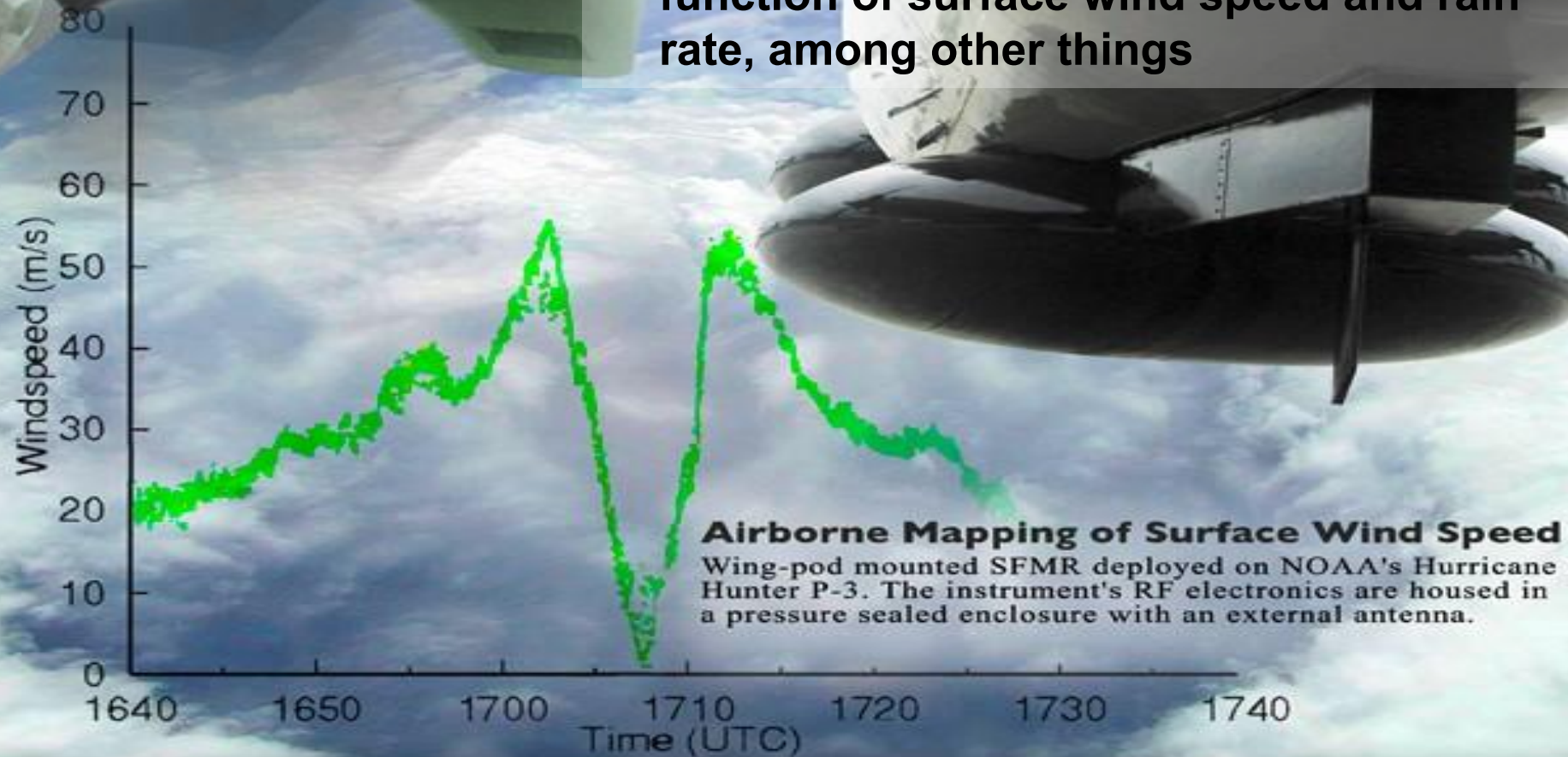
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STEPPED FREQUENCY MICROWAVE RADIOMETER

- SFMR measures microwave emission from foam (air bubbles in the ocean)
- Measured microwave emission is a function of surface wind speed and rain rate, among other things



SFMR Issues

- Shoaling – breaking waves in areas of shallow water can artificially increase the SFMR retrieved wind and invalidate the observations
- Interaction of wind and wave field can introduce errors ~ 5 kt
- Rain impacts not always properly accounted for (mainly < 50 kt)
- Calibration is an ongoing process
- High SFMR winds seen in strong storms in 2017-2020 compared to flight-level wind reduction

Summary

- Aircraft data are extremely valuable, and provide direct measurement of wind and pressure data in tropical cyclones
- However, all data have strengths and weaknesses when being used to assess tropical cyclone intensity in real time and post analysis
 - Representativeness
 - Sampling
 - Vertical adjustment
 - Calibration
- Significant uncertainty exists in the analysis of intensity and wind radii
 - Intensity only good to within $\sim 10\%$ (e.g., 100 kt \pm 10 kt)
 - TS wind radii to about $\sim 25\%$ (e.g., 120 nm \pm 30 nm)
 - HU wind radii to about $\sim 40\%$ (e.g., 25 nm \pm 10 nm)
- Even “well sampled” storms still have wide swaths of unsampled territory